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New Developments in Technology Management Education: Background Issues, Program Initiatives, and a Research Agenda

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We provide background information on key developments and trends in technology management education, including the managerial implications of recent public policy changes designed to stimulate investment in technology and entrepreneurship. We then consider the educational implications of these trends, drawing on lessons learned from papers in the special issue and our own research. Finally, we outline an agenda for future research on technology management education.

INTRODUCTION

The teaching of technology management has a long history in business schools. However, the nature and focus of such curricula have changed in recent years, due to several trends. The rise of a knowledge-based economy has brought greater attention to the management and commercialization of intellectual property (Markman, Siegel, & Wright, 2008). Questions regarding the appropriate business models to foster successful commercialization have been further complicated by the rise of "open-source" innovation (e.g., Linux, a software company that has captured substantial market share). And new institutions (e.g., incubators and science parks; Phan, Siegel, & Wright, 2005) and new organizational forms (e.g., research joint ventures [RJVs], and technology alliances) have emerged that may also have profound effects on technology management education. Nonprofit institutions, most notably universities and federal laboratories, have become much more aggressive in protecting and exploiting their intellectual property (Siegel & Wright, 2007). Such institutions, especially universities, are also working much more closely with industry and government.

These trends and growing involvement of government and nongovernmental institutions in innovation and commercialization have led to growing international recognition of the narrowness of technology management education as it is practiced today. Some business and engineering schools have responded to these developments by designing new courses and curricula related to technological entrepreneurship. Some countries with centralized educational systems (e.g., Japan, Singapore, and Ireland) are graduating "bilingual engineers" with capabilities in technology and business. Yet, this trend of marrying technology with management education is still far from being in the mainstream.

Another important development in stimulating and changing the nature of the demand for technology management education is the rise of knowledge and intellectual property management as a professional field. In many countries, national governments have supported these initiatives by enacting legislation to facilitate public–private research partnerships, technology transfer (through patenting and licensing) from universities to firms (e.g., the Bayh–Dole Act of 1980), and collaborative research. For example, the EU, China, and Singapore have established technology-based venture funds to stimulate the development of technology-based start-up companies. In the United States, the national "public sector venture capital" for technology-based new ventures, the Small Business Innovation Research (SBIR) program and numerous state-level programs with similar goals (e.g., Ben Franklin Technology Partners, Pennsylvania, and the Massachusetts Technology Development Corporation) have propelled technology transfer issues to the forefront of university technology management curricula.

Government is also providing subsidies for research joint ventures involving universities and firms (e.g., the Commerce Department's Advanced Technology Program/Technology Innovation Program), shared use of expertise and laboratory facilities (e.g., the National Science Foundation's Engineering Research Centers and Industry–University Cooperative Research Centers), and programs to promote management and entrepreneurship education among scientists and engineers (e.g., the Science Enterprise Challenge in the U.K.). These and other trends discussed here have led to experimentation and innovation in technology management pedagogy and content, which is the focus of this special issue.

For example, it is obvious that the rise in collaborative research and commercialization has important educational implications, since it implies that team-work has become more important in science and engineering, especially when both innovation and commercialization are involved. This has resulted in the increasingly popular use of real-life team projects as the primary method of delivering discovery-based learning.

Our purpose in this special issue is to assess the implications of these trends for technology management curricula in business schools. In spring 2008, we issued an open Call for Papers on the Academy of Management website, the Social Science Research Network, and other venues. We received 38 manuscripts, which were reviewed according to *AMLE* standards for the Research & Reviews section. Papers were also solicited for the Essays, Dialogues, & Interviews and Exemplary Contribution sections, which were subject to the usual peer-review process. Based on the results, we selected several manuscripts for inclusion which are summarized in Table 1.

The remainder of this essay is organized as follows: First, we describe recent public policy changes, which have promoted university–industry partnerships, collaborative research, and technology transfer from universities and federal labs to the private sector. Then, we discuss the educational implications of these trends, drawing on some of the lessons learned from the papers in special issue. Finally, we outline an agenda for additional research on technology management education.

PUBLIC POLICY INITIATIVES INFLUENCING TECHNOLOGY MANAGEMENT

In recent decades, we have witnessed rapid growth in the incidence of a variety of research partnerships and technology commercialization involving corporations, universities, nonprofit organizations, and government agencies. This growth can be attributed to three policy initiatives:

- Policies promoting the transfer of technology from universities and federal labs to firms
- A large increase in the incidence of public–private partnerships
- Relaxation of antitrust enforcement related to collaborative research

Examples of such technology partnerships are research joint ventures, strategic alliances and networks involving high-technology organizations, industry consortia (e.g., SEMATECH), cooperative research and development agreements (CRADAs) involving federal labs and firms, engineering research centers (ERCs), and industry–university cooperative research centers (IUCRCs) sponsored by the U.S. National Science Foundation, federally funded research and development centers, science parks and high-technology incubators (many of which are located at universities), and licensing and sponsored research agreements involving universities, government laboratories, firms, and university-based start-ups.

Table 2 summarizes the key U.S. legislation promoting government–university–industry partnerships, collaborative research, and technology transfer/commercialization. The most important legislation in this regard is the Bayh–Dole Act of 1980, which dramatically changed the rules of the game with respect to the ownership of intellectual property rights of technologies emerging from federal research grants. Bayh–Dole conferred the right to universities to patent and claim the scientific discoveries arising from U.S. government-funded research, instituted a uniform patent policy across federal agencies, and lifted numerous restrictions on technology licensing. As a result of this legis-

TABLE 1
Summary of Papers

Authors	Key Research Question	Theory/Framework	Data/Methods	Findings/Conclusions
Barr, Baker, Markham, & Kingon	Discovering how to teach technological entrepreneurship skills that will help bridge the "valley of death" in COT between creation of technology and emergence of a commercial venture.	Van Burg et al. (2008) science-based design framework of five factors critical to enhance science-based start-ups; cognitive theory; theory of planned action.	Analysis of development of a COT program for MBA, PhD, and master's students at North Carolina State over 14-year period.	Enactive mastery experiences have to be perceived as authentic and real to have desired effect; importance of loosely structured hands-on engagement; program needs to be real, intensive, interdisciplinary and iterative; need to create temporal checkpoints, decenter business plans, to structure large blocks of time, to emphasize and balance team diversity, generate technology flow, beware of idiosyncratic heuristics.
Thursby, Thursby, & Fuller	What are the benefits and challenges of integrated approaches to graduate education in technological entrepreneurship?	Theory of the Firm—Economic Approach to Evaluation.	Ordered logit analysis of program assessment data including pre- and postsurveys and a control group relating to a NSF-sponsored integrated program at Georgia Tech and Emory University involving PhD, MBA, and JD students.	Significant positive effects of the program on student perceptions of the multi-disciplinary capabilities needed to operate in a technological business environment.
Austin, Nolan, & O'Donnell	How to design a student experience in technology management that addresses the learning cycle more completely, while maintaining very high levels of student engagement.	Experiential learning theory.	Programs at universities in two countries, MNC executives, and open enrollment course at a business school; combination of case and traditional lecture-based approaches; narrative approach based on monomyth; student course feedback and follow-up 1 year later.	Approach works at multiple student levels with same materials but emphasis differs across groups; able to use with introductory and capstone courses; approach acts as a leveler in class as all can engage with the 'story'; issues concerning integration of supplementary materials, lack of 'closure' in each class, use of fictionalized cases.
Verzat, Byrne, & Fayolle	What teaching methods can be used to create entrepreneurial engineers that have a keen sense of teamwork? Are games an appropriate pedagogical device to meet the specific learning needs of engineering students? Can games help engineering students learn about teamwork?	Education science and team process; Kirkpatrick's 4-level hierarchy of evaluation.	Use of team games in a traditional elitist French teaching context that emphasizes individual learning; evaluation data collected from 111 groups on initial reaction to the game and interviews 3 months later.	Games rated a positive reaction from students despite being an informal departure from normal formal approach; real learning outcome in exposing students to importance of team working.
Boni, Weingart, & Evenson	How to teach skills of creating disruptive innovations and develop new business opportunities through blending entrepreneurial thought and action, design thinking, and team building.	Disruptive innovation, entrepreneurial leadership, design thinking, and team building.	Capstone course for MBA Entrepreneurship in Organizations & Design master's students at Carnegie Mellon involving team teaching; Multidisciplinary teams of designers, technologists, and business student entrepreneurs.	It is important to blend three perspectives for effective commercialization of innovation: (1) entrepreneurial thought and action, (2) design thinking, and (3) team-building. A key feature of this project-based course is the collaboration between MBA students and School of Design students, which leads to the development of new business opportunities.

(table continues)

TABLE 1
Continued

Authors	Key Research Question	Theory/Framework	Data/Methods	Findings/Conclusions
Clarysse, Mosey, & Lambrecht	What are implications for developments in technology management education of contemporary challenges such as globalization, open innovation, and the need for corporate renewal (and venturing)?	Technology management skills provision.	Qualitative analysis based on interviews with 10 technology management education demand- and supply-side actors in universities, consultancies, and corporations across Europe.	Technology Management Educations is a dynamic field moving from traditional MBA focused programs towards more entrepreneurial 'bootcamps', from a case study oriented teaching style towards a mentoring approach and from an emphasis upon general business towards working across disciplines yet being sensitive to underlying technologies; a shift from general to specific skills; Linkages between business schools and technology schools is an important element of this change.
Hang, Ang, Wong, & Subramanian	How can management of technology programs & curricula be designed to meet the needs of a small newly developed Asian country?	Action learning as a foundation for curriculum design in technology intensive technology management programs.	Qualitative analysis of transfer of MSc in Management of Technology from business school to a school of engineering in Singapore	Courses in IP management, management of industrial R&D, systems architecture and engineering could only be offered by transfer to School of Engineering; traditional professional degrees can be enhanced by integrating management of technology programs into core engineering curriculum; advantages of offering part-time courses for those in employment.
Mustar	How to develop a highly selective technology management course for students in a leading French engineering school, in an institutional and country environment traditionally resistant to the notion of entrepreneurship, that develops their entrepreneurial skills but which goes beyond an introductory course on how to start a business. How to combine the acquisition of knowledge and the development of skills. How to develop their entrepreneurial skills and their ability to take responsibilities. How to encourage imagination, creativity, involvement, and risk taking.		Qualitative analysis of the case of innovation and entrepreneurship in Mines Paris-Tech, a leading French engineering school.	Need to find a subtle balance between traditional didactic courses, presentations of leading edge research, workshops and meetings with practitioners, field studies and involvement in real projects through internships (including outside France); need for faculty to have close links with industry both domestically and abroad; important use of concurrent teaching modes.

lation, U.S. research universities established technology transfer offices to manage and protect their intellectual property. The Stevenson–Wydler Act, enacted in the same year as Bayh–Dole and then extended in 1986, required federal labs to adopt technology transfer as part of their mission and also authorized cooperative research and development agreements (CRADAs) between the labs and private organizations.

The National Cooperative Research Act (NCRA) of 1984 and the National Cooperative Research and Production Act (NCRPA) of 1993, promoted collabo-

TABLE 2
Key U.S. Legislation Promoting Government–University–Federal Lab–Industry Partnerships, Collaborative Research, Technology Transfer/Commercialization

Legislation	Key Aspects of Legislation	Institutions Affected by Legislation
Bayh–Dole Act of 1980	Transferred ownership of intellectual property from federal agencies (which sponsor most basic research) to universities; Spurred the growth of university technology transfer offices, which manage university patenting and licensing.	Universities; teaching hospitals; firms
Stevenson–Wydler Technology Innovation Act of 1980; Federal Technology Transfer Act of 1986	Required federal labs to adopt technology transfer as a part of their mission; Authorized cooperative research and development agreements (CRADAs) between federal labs and private organizations.	Federal labs; firms
Small Business Innovation Development Act of 1982	Created the Small Business Innovation Research (SBIR) and the Small Business Technology Transfer (STTR) programs, which require each federal agency to allocate a percentage (now 2.5%) of their research budget to small business research with commercial potential.	Universities; small firms; venture capital firms
National Cooperative Research Act (NCRA) of 1984; National Cooperative Research and Production Act (NCRPA) of 1993	NCRA and NCRPA actively encouraged the formation of research joint ventures and joint production ventures among U.S. firms.	Firms; universities
Omnibus Trade and Competitiveness Act of 1988; America COMPETES Act (2007)	The 1988 act established the Advanced Technology Program (ATP), a public–private research program. In 2007, the America COMPETES Act created the successor to ATP, the Technology Innovation Program (TIP).	Firms; universities

rative research by eliminating antitrust concerns associated with joint research even when these projects involved firms in the same industry. The NCRA created a registration process, later expanded by the National Cooperative Research and Production Act (NCRPA) of 1993, under which research joint ventures (RJVs) can disclose their research intentions to the Department of Justice. The most notable research joint venture established via the NCRA registration process was SEMATECH (SEmiconductor MAnufacturing TECHnology), a not-for-profit research consortium, which provided a pilot manufacturing facility, where member companies could improve their semiconductor manufacturing process technologies.

Other legislation created two key publicly funded technology programs: (1) the Small Business Innovation Research (SBIR) and the Small Business Technology Transfer (STTR) programs, which require each federal agency to allocate a percentage (now 2.5%) of their research budgets to small businesses with commercial promise, and (2) the Advanced Technology Program (ATP), a public–private research program, which funds collaborative research on generic technologies. In 2007, the America COMPETEs Act created the successor to ATP, the Technology Innovation Program (TIP). Universities are actively involved in both programs, working closely with large firms on ATP/TIP research projects, as well as with small companies on SBIR/STTR, sometimes founding these firms. As a result, many technology management curricula in the United States are now infused with a public policy dimension that was previously missing.

Table 3 presents global evidence on key policy changes relating to the legislative and support environment for technology commercialization in five nations: France, Germany, Italy, Singapore, and the United Kingdom. For example, according to Meyer (2008), Austria, Denmark, Finland, Germany, Italy, and Japan have adopted "Bayh–Dole like" legislation, emphasizing a "patent-centered" model of university and national laboratory technology transfer. The United Kingdom and Israel have always had a system of university-owned

TABLE 3
Legislative and Support Environment for Technology Commercialization in France, Germany, Italy, Singapore, and the U.K.

Milestone	France	Germany	Italy	Singapore	U.K.
I. University Ownership of Intellectual Property Arising From Federal (National) Research Grants (e.g., Bayh–Dole Act in U.S.)	Not relevant as all IP belongs to universities/public research institutes following the "*code intellectuelle de la propriete*."		1999 Public researchers receive the right to be the owner of their IP. This is the opposite of the Bayh–Dole Act, but oftentimes the university makes a formal contract on an individual basis to give the IP rights to the university.	1963 Forms tripartite macroeconomic structure of industry, labor, and government as basis for funding innovation and economic development. 2001–2008 National initiative to focus on microelectronics, biotechnology, nanotechnology, materials science, healthcare and life sciences as part of national innovation initiative. The right to commercialize IP are assigned to the faculty.	No formal Bayh–Dole Act. In the case of UK public research organizations the IP is owned by the institution and the royalties associated with the IP are distributed between the relevant parties. The distribution of royalties is organized on an institutional basis.
II. Other Key Changes	1999 Innovation Act gives the possibility to academics who are civil servants to participate as a partner or a manager in a new company and to take equity (previously illegal for civil servants). This Act encourages the creation of new start-up firms by students. 2002 Decree that regulates and increases the personal income an academic can receive from IP (50%).	2002 Employer Invention Law: Invention belongs to the employer not to the professor.	2000–2006 Restructuring of various laws to make it easier to commercialize technology from universities, get part of the royalties as an academic, take equity in start-ups, etc.	2001 Economic Development Board charged with the implementation of the 5-Year Science and Technology Plan which includes initiatives to target key technology sectors, attract foreign investment and human capital, and accelerate technological entrepreneurship and technology commercialization. Agency for Science, Technology and Research or A*STAR) created to fund and create infrastructure of industry–university joint research efforts in strategic technology sectors.	
III. Financial Support	1999 11 (pre-) seed capital funds created to invest in innovative start-ups and take equity (investment in 150 spin-offs in 8 yrs). Creation of the annual National Competition for the creation of technologically innovative start-ups (grant from 45,000 to 450,000 Euros); 12,927 projects have been presented between 1999 and 2007: 1,879 have been funded. Creation of 29 incubators between 1999 and 2007; they hosted 1993 projects giving birth to 1,239 new firms. Between 1999 and 2007, these 3 schemes have benefited 1,760 new firms (taking into account that a company can benefit from different schemes). Around 50% are academic spin-offs.	2000 EXIST: public program that assists spin-offs through preseed capital and management support. 2002 EEF-Fund: Researchers can receive a scholarship to start a spin-off. 2002 22 TTOs established which take care of IP management.	1999 National Research Commission created, which annually funds about 5-10 proposals for spin-offs, amounting to 30,000 Euro, on average. 2005 Quantica Fund. First interuniversity seed capital fund (a form of public–private partnership) is created. 2005 Italian University technology transfer offices have to join together in groups of four and bid for money (100,000 Euro/university) to sponsor their day-to-day operations.	2005 The government's funding plan is to increase R&D expenditure to 3% of GDP by 2010, from the 2004 R&D expenditure of $2.5 billion US (about 2.25% of GDP). 2007 Public sector R&D budgets more than doubled to $13.55 US billion from 2005, comprised of $5 billion US for the National Research Foundation (NRF), $5.4 billion US for the Public Research Institutes housed in the Agency for Science, Technology and Research (A*STAR). $1.05 billion US for academic (university-based) research. $2.1 billion US for the Economic Development Board (EDB) to promote private sector R&D.	1970 onward Various schemes to promote collaborative projects between universities and industry, including Knowledge Transfer Networks. 1998–2004 Higher education reaches out to business and the community to provide funding to establish corporate liaison offices and collaborative projects. 1998 University Challenge Funds (UCFs): Universities were granted funds to support spin-off and limited incubation support. 2001 onward HEIF (Higher Education Innovation Fund) provides permanent flow of funding to support & develop universities' capacity to act as drivers of growth in the knowledge economy (various rounds up to 2008).

(*table continues*)

TABLE 3
Continued

Milestone	France	Germany	Italy	Singapore	UK
	In 2005, six "*Maisons de l'entrepreneuriat*" in different universities have been created. They aim at facilitating the promotion of the entrepreneurial spirit and mind-set and "sensitization" to the new business start-up or new activities.				Science Enterprise Challenge funding (1991/2001), to encourage culture open to entrepreneurship required for successful knowledge transfer from science base. Teaching entrepreneurship to support the commercialization of science and technology to produce graduates and postgraduates better able to engage in enterprise. Establish a network of UK universities specializing in teaching and practice of commercialization and entrepreneurialism in science and technology. 2005 Medici Fellowship Scheme, pilot providing 50 fellowships over 2 years focusing on commercialization of biomedical research; fellows required to have significant prior research; local training in host institution in finance, marketing, IP, & business strategy; fellows encouraged to develop links with practitioners; postpilot further funding obtained to extend remit to include engineering researchers from 2007–2009; analogous schemes subsequently created by Research Councils and Regional Development Agencies and from 2007–2009 mainly focused in life sciences. Regional Development Agencies providing broad spectrum of assistance to develop more productive links between universities and industry. 2007–2011 Technology Strategy Board strategic plan envisages investing £1 billion of public funds plus matched funds from industry over 2008-2011, in doubling number of innovation platforms, a strategic review of Knowledge Transfer Networks, doubling number of Knowledge Transfer Partnerships, developing strategy to rapidly commercialize new and emerging technologies, piloting a new Small Business Research Initiative.

Information sources: Clarysse et al. (2007); Mustar & Wright (2009); and Koh & Phan (In Press).

intellectual property. An increase in funding for technological entrepreneurship in many countries (see Table 3) has also stimulated greater interaction among firms, universities, and national labs, as well as the rise of intellectual property management curricula and courses at these institutions (for detailed comparison of France and the U.K., see Mustar & Wright, 2009).

EDUCATIONAL IMPLICATIONS OF THESE TRENDS

The end result of these global trends is an increased emphasis on collaborative research, commercialization of intellectual property, entrepreneurship, venture capital, and research centers dedicated to emerging technologies, such as Organic LEDs, nanotechnology, biotechnology, materials science, MEMS, and so on. Such trends have brought new issues and perspectives, propelling the role of education to the forefront of discourse (e.g., the recent *AMLE* special issue on entrepreneurship education). Conventional technology management and management of innovation curricula have focused largely on understanding the technology and innovation strategies of multinational firms (Nambisan & Willemon, 2003). There has been, until recently, less emphasis on start-up and entrepreneurial technology-based firms. The differences can be significant. For example, in the traditional curriculum, the role of teamwork, especially linking interdisciplinary teams of agents (scientists, technology managers, and entrepreneurs) and institutions (firms, universities, government agencies) have not been stressed. That is, the individual and institutional levels of analyses have been ignored, such that technology management education curricula have been confined to how organizations respond to technological challenges.

The developments in technology management education considered in this special issue can be seen as a response to the challenges leveled at business schools to be relevant to the practice of management (Pfeffer & Fong, 2002, 2004; Starkey, Hatchuel, & Tempest, 2004). At the same time, such programs that reside in business schools, when detached from the engineering and science faculties of their universities, run the risk of treating the technology component as a special case of general management. Our review of the literature and the lessons learned from this special issue suggest that a fully matured technology management program should treat technology with a capital "T" rather than the small one it has been to date. To accomplish this design goal, business schools need to appoint program directors with strong boundary-spanning skills that can link up with technology-based units on and off campus by colocating or partnering with such institutions.

We note that the challenge of integration is not easily solved. Over the years, business schools in the United States and United Kingdom have chosen to remain independent from the rest of their universities. This was partially enabled by the largesse of endowments in the 1980s and 1990s pouring in from private foundations and industrialists seeking to establish their names in perpetuity. Clarysse, Mosey, and Lambrecht (this issue) hypothesize that this is not a wise strategy for business schools administering technology management curricula. The authors conclude that business schools should expand their educational mission to include the education of engineering and science professors and researchers, and the training of postgraduate science and engineering students, since these individuals are more likely to choose an industry or technology-specific master's degree, instead of a traditional MBA. More generally, business schools need to have a stronger connection to schools of engineering and the sciences, and other technology-orientated organizations in the areas of medicine, public health, and pharmacy, as well as science-based business incubators and science parks.

While acknowledging Clarysse et al.'s points, we are concerned that each of these institutions has different paradigms, norms, standards, and values, as well as diverse languages and codes. Thus, it may be necessary to develop a shared syntax of boundary objects that include repositories, standardized forms, objects and models (Carlile, 2002). These communication devices enable individuals in business schools and technology-based schools to learn about their differences and dependencies, as well as jointly to evolve their knowledge bases about how things work "on the other side." Hence, the recruitment and development of boundary spanners (such as program managers, center directors, or interdisciplinary faculty members) who can communicate across schools are important to facilitate such integration (see e.g., the Medici Scheme, Table 3).

Another concern regarding the optimal design of technology management curricula arises in relation to the overall configuration of business schools. Ambos, Makela, Birkinshaw, and D'Este (2008) have argued that for universities to be effective at technology commercialization there is a need for ambidexterity in the organizational structures of these traditional research and teaching institutions. Similarly, with respect to technology management education, business schools must make their organizations more porous, for example, through the hiring and promotion of faculty with science and engineering degrees. Such ambidexterity configurations will enable business schools to more tightly bind the traditional business disciplines to science and engineering disciplines.

The papers in this special issue challenge the proposition of Suddaby and Greenwood (2001), who asserted that business schools can sustain demand for new managerial knowledge through the education and accreditation of a continuing stream of management students. While it is true that there has been substantial growth in demand for courses in entrepreneurship and innovation in MBA and undergraduate programs, the ability of business schools to deliver these programs beyond an introductory level is open to debate, especially when faculty in such schools traditionally lack exposure to the hard sciences and technology disciplines.

A third concern in the design of technology management curricula raised herein is the notion of avoiding polar extremes in content coverage, which are emphasizing theoretically rigorous, but highly abstract research or stressing practical content based on "war stories" and conventional wisdom. Placing too much emphasis on practical experience may have negative consequences since the mental models that such pedagogies create can quickly become obsolete, particularly in light of the fast evolving technologies the curricula are supposed to address (Locke & Schöne, 2004). In other words, practice-oriented technology management curricula may inspire students to become more entrepreneurially oriented, but without the concomitant development of critical thinking skills, such as the ability to assess risks and recognize the inevitable downsides of entrepreneurial activity. Technology management curricula that are light on practice, however, can produce students who may find the challenge of boundary spanning, a key skill for successful technology managers, too great to scale.

Van Burg, Romme, Gilsing, and Reymenk (2008) have outlined a design science-based model for the development of academic spin-offs that is grounded in both theory and practice. As noted by Barr, Baker, Markham, and Kingon (this issue), new developments in technology management education stress the importance of active involvement (experiential learning) models that are authentic and real.

Many technology management curricula mimic those of entrepreneurship, in that they include a healthy dose of business plan writing, ostensibly as products of courses on commercialization and opportunity search. There is considerable debate over the usefulness of business plans in practice, even though venture capitalists and banks demand them. Indeed, Barr, Baker, Markham, and Kingon (this issue) challenge the effectiveness of teaching the preparation of a business plan. They suggest that it is preferable to deemphasize the writing of a plan because it tends to restrict creativity and the search for more appropriate solutions. Yet, as a pedagogical tool, we think that business plans, when used appropriately, can be a useful way to garner a student's attention on a comprehensive set of issues that should be considered when commercializing an invention.

A shift is taking place from traditional technology management curricula toward more entrepreneurially based courses that require interdisciplinary skills. As part of this development, there is a need for interdisciplinary team-learning activities to be a central part of curriculum development in technology management education. Team composition needs to be addressed carefully to enable participants to gain full benefits. Thursby, Thursby, and Fuller (this issue) present an interesting example of teams of law, business, science, and engineering students converging to commercialize innovations developed at Emory University and the Georgia Institute of Technology.

Developments in technology management education also pose major faculty recruitment challenges. Many business school faculty members do teaching, research, and service (including consulting) that is focused on large corporations. Traditional business school academics typically lack the appropriate context-specific business creation skills that are increasingly demanded as central to technology management education (Wright, Piva, Mosey, & Lockett, 2008). As noted in Barr, Baker, Markham, and Kingon (this issue), the recruitment of adjunct faculty members should be focused on those who can serve as mentors to students. There is also a need to consider recruitment and training of faculty who can act as boundary spanners. The time-consuming nature of developing interdisciplinary curricula raises a concern about possible conflicts with the promotion-and-tenure process, which also needs to be addressed in recruitment and retention.

AGENDY FOR FURTHER RESEARCH ON TECHNOLOGY EDUCATION

To build on the findings of this special issue, we identify a number of areas for further research.

These are summarized in Table 4, where we identify a series of research questions relating to institutional issues, the interaction between education and practice, the advancement of business schools, and evaluation.

Universities typically have well-established conventions and practices concerning the management of their activities. The traditional academic culture of the university (the classic "ivory tower") embodies a system of values that opposes the commercialization of research through company creation. When university administration is decentralized, with no mechanism for integration, links between business schools and technology-oriented units of universities may be weak or informal. This suggests a need for the development and implementation of clear and well-defined strategies, processes, and policies regarding new venture formation and approaches to technology management education that incorporate entrepreneurial activities.

Institutional frictions and their impact upon intraorganization knowledge transfer are well-known (Szulanski, 1996). These frictions in the interactions between different elements of the university may frustrate the development of interdisciplinary technology management curricula. Transferring personnel across organizational boundaries has been identified as an important mechanism to effect knowledge transfer (Inkpen & Tsang,

TABLE 4
Research Agenda

Institutional Issues	Interaction Between Education and Practice	Advancement of Business Schools	Evaluation Issues
How do incentive systems for faculty encourage the time-intensive development of effective technology management courses?	How can technology management education processes be transferred to promote the creation and development of spin-offs?	How can the necessary specific skills now required for technology management education be developed within business schools?	How effective are different developments in technology management education?
What institutional challenges constrain the cross-disciplinary development of technology management education?	How can universities develop integration processes among technology management education and technology transfer offices, incubators, and science parks?	Do business schools have the requisite career structures for faculty involved in technology management education? (e.g., adjunct, nontenure track faculty).	Is it possible to have a valid control group in evaluation of technology management education?
What are resource implications for universities attempting to develop inter-disciplinary technology management education?	How can business schools enhance (effective) engagement with leading-edge technological entrepreneurs?	What is the role of business school faculty in contributing to the development of technology management education?	From a corporate perspective (since many students are sponsored by companies), how effective are technology management programs?
What decision making processes are most effective in promoting interdisciplinary teaching and research, and integration in technology management education (top-down vs. bottom-up)?	What are the roles of different competitors within the segments of the broad technology management space?	What challenges arise in addressing "language barriers" between business school and technology/ engineering faculty and how can they be overcome?	What are the most appropriate methods for evaluating the effectiveness of technology management education?
Does development of technology management education represent a need to reevaluate the whole position of business schools within universities, or is there a need for ambidexterity?	What is the best way to train technology managers who must engage in boundary spanning among industry, the entrepreneurial community, academia, and government?	What challenges arise in integrating research with new developments in technology management education?	Is it possible to build evaluation into the design of technology management education programs, so we can identify "best practices" and benchmark comparable programs?

2005). Universities may need to consider the facilitation of exchanges of staff between schools or the development of faculty with boundary-spanning skills.

Academics may identify more closely with their discipline than with the business school or university and may seek to marginalize "tribes" from "outside disciplines" (Becher & Trowler, 2001). This concern is especially salient if the objective is to integrate research with new developments in technology management education. Differences in language and goals between business schools and science- and technology-based departments exacerbate these problems. Business schools may also lack credibility with conventional, "pure" scientists, who perceive them as professional schools with little research tradition. This may be a major issue in universities with strong science departments and weak business schools (Wright et al., 2008). However, even this effect is likely to vary between disciplines, as some departments, for example, engineering and medicine, may be closer in the sense of being professional schools than the pure science departments.

It may also be important to focus on the role of technology managers within the university. Siegel, Waldman, and Link (2003) found that the key impediment to effective university technology transfer tended to be organizational in nature. In a subsequent field study (Siegel, Waldman, Atwater, & Link, 2004), the authors found there are deficiencies in the technology transfer office and other areas of the university involved in technology commercialization with respect to marketing skills and entrepreneurial experience. This finding has been confirmed with more systematic data by Markman, Phan, Balkin, and Gianodis (2004), who explained this result by reporting that universities were not actively recruiting individuals with such skills and experience. Instead, representative institutions appear to be focusing on expertise in patent law and licensing or technical expertise. To develop effective curricula, the expertise that business school faculty need to interact with science and technology departments may be discipline specific. Yet the background of business school faculty typically makes it difficult for them to convey sufficiently context-specific material for different groups of technologists. To this end, Siegel and Phan (2005) suggest the creation of formal training programs for university personnel on the issue of technology management.

Thursby, Thursby, and Fuller (this issue) report that an integrated graduate program on technological entrepreneurship has a positive impact on student perceptions of the multidisciplinary capabilities needed to operate in a technologically oriented business environment. Taking a page from Souitaris, Zerbinati, and Al-Laham (2007), who drew on the theory of planned behavior to demonstrate that entrepreneurship programs raised risk-taking attitudes and inspired entrepreneurial intention among students, we suggest that technology management curricula can similarly inspire students to think creatively about how they can convert science to commercial ventures by immersing them in the experience of technology and opportunity evaluation early on in the program.

Authors of evaluation studies need to find ways of incorporating the measurement of postprogram outcomes, such as new venturing and career trajectories, through more longitudinal studies. More specifically, it would be extremely useful to build evaluation into the design of such programs, so that we can identify "best practices" and benchmark comparable programs as we do for other types of programs. A critical methodological issue in evaluation concerns whether it is possible to have a viable control group for such a study.

The papers in this special issue represent a number of different institutional contexts worldwide. A final question one can ask, after reading these papers, is whether there are developments that suggest a convergence in program design towards a universal model, or are we likely to experience a wide variation due to adaptations to the local contexts? Locke and Schöne (2004) highlight important differences in the interaction between business schools and industry in Europe compared to those in the United States. They suggest that the relations between business school faculty and other scientists have traditionally been stronger in the United States than in the United Kingdom and France. Further, subjects taught in business schools in France, the United Kingdom, and the United States tend to be close to praxis, and professors have usually had practical experience. To contrast, in Germany management education has always been strongly oriented toward science, with academics having little business experience/contact with industry; this pattern appears to have persisted despite pressure for convergence to an Anglo-Saxon business school model (Muller-Camen & Salzgeber, 2005). Mustar (this issue) and Verzat, Byrne, and Fayolle (this issue) illustrate the challenges of introducing entrepreneurial elements to the traditional approach to technology and engineering training in France. Hang, Ang, Wong, and Subramanian (this issue) argue that there was a need to design a program to meet the needs of a small newly developed Asian country.

In sum, while the elements of technology management curricula appear to be very similar, in part driven by the institutional hegemony of U.S.-based models, there is some indication of local adaptation in pedagogy, delivery mechanisms, and sequencing of content, based on government initiatives, types of corporations that employ the local graduates of such programs, and the capabilities of the universities delivering them.

REFERENCES

Ambos, T., Makela, K., Birkinshaw, J., & D'Este, P. 2008. When does university research get commercialized? Creating ambidexterity in research institutions. ***Journal of Management Studies,*** 45: 1424–1447.

Becher, T., & Trowler, P. R. 2001. ***Academic tribes and territories.*** Buckingham: The Society for Research into Higher Education and Open University Press.

Carlile, R. P. 2002. A pragmatic view of knowledge and boundaries: Boundary objects in new product development. ***Organization Science***, 13: 442–455.

Inkpen, A., & Tsang, E. 2005. Social capital, networks and knowledge transfer. ***Academy of Management Review,*** 30(1): 146–165.

Koh, W., & Phan, P. In Press. The National Innovation System in Singapore. In V. K., Narayanan, & G. O'Connor, (Eds.), ***Encyclopedia for Technology, Innovation and Management,*** Blackwell Press: U.K.

Locke, R., & Schöne, K. 2004. ***The entrepreneurial shift: Americanization in European high-technology management education.*** Cambridge: Cambridge University Press.

Markman, G., Phan, P., Balkin, D., & Gianiodis, P. 2004. Entrepreneurship from the ivory tower: Do incentive systems matter? ***Journal of Technology Transfer,*** 29(3–4): 353–364.

Markman, G., Siegel, D., & Wright, M. 2008. Research and technology commercialization. ***Journal of Management Studies,*** 45: 1401–1423.

Meyer, M. 2008. ***University patenting and IP management approaches in Europe.*** Brighton: SPRU, University of Sussex.

Muller-Camen, M., & Salzgeber, S. 2005. Changes in academic work and the chair regime: The case of German business administration academics. ***Organization Studies,*** 26(2): 271–290.

Mustar, P., & Wright, M. 2009. Convergence or path dependency in policies to foster the creation of university spin-off firms? A comparison of France and the United Kingdom. ***Journal of Technology Transfer,*** forthcoming.

Nambisan, S., & Willemon, D. 2003. A global study of graduate management of technology programmes. ***Technovation,*** 23: 949–962.

Pfeffer, J., & Fong, C. T. 2002. The end of business schools? Less success than meets the eye. ***Academy of Management Learning and Education,*** 1(1): 78–95.

Pfeffer, J., & Fong, C. T. 2004. The business school "business": Some lessons from the U.S. experience. ***Journal of Management Studies,*** 41(8): 1501–1520.

Phan, P., Siegel, D. S., & Wright, M. 2005. Science parks and incubators: Observations, synthesis and future research. ***Journal of Business Venturing,*** 20(2): 165–182.

Siegel, D. S., & Phan, P. 2005. Analyzing the effectiveness of university technology transfer: Implications for entrepreneurship education. In G. D. Libecap, (Ed.), ***Advances in the study of entrepreneurship, innovation, and economic growth, volume 16: University entrepreneurship and technology transfer:*** 1–38. JAI Press: Oxford, UK.

Siegel, D. S., Waldman, D., & Link, A. N. 2003. Assessing the impact of organizational practices on the productivity of university technology transfer offices: An exploratory study. ***Research Policy,*** 32(1): 27–48.

Siegel, D. S., Waldman, D., Atwater, L., & Link, A. N. 2004. Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: Qualitative evidence from the commercialization of university technologies. ***Journal of Engineering and Technology Management,*** 21(1–2): 115–142.

Siegel, D. S., & Wright M. 2007. Intellectual property: The assessment. ***Oxford Review of Economic Policy,*** 23(4): 529–540.

Souitaris V., Zerbinati, S., & Al-Laham, A. 2007. Do entrepreneurship programmes raise entrepreneurial intentions of science and engineering students? The effects of learning, inspiration and resources. ***Journal of Business Venturing,*** 22(4): 566–591.

Starkey, K., Hatchuel, A., & Tempest, S. 2004. Rethinking the business school. ***Journal of Management Studies,*** 41(8): 1521–1532.

Suddaby, R., & Greenwood, R. 2001. Colonizing knowledge: Commodification as a dynamic of jurisdictional expansion in professional service firms. ***Human Relations***, 54: 933–953.

Szulanski, G. 1996. Exploring internal stickiness: Impediments to the transfer of best practice within the firm. ***Strategic Management Journal,*** 17: 27–43.

Van Burg, E., Romme, G. L., Gilsing, V. A, & Reymenk, I. M. M. J. 2008. Creating university spin-offs: A science-based design perspective. ***Journal of Product Innovation Management,*** 25: 114–128.

Wright, M., Piva, E., Mosey, S., & Lockett, A. 2009. Academic entrepreneurship and the role of business schools. *Journal of Technology Transfer*.

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